**Response to Reviewers’ Comments**

**Date**: May 19, 2023

**Manuscript Number**: AGEE36058

**Title of Article**: A predator in need is a predator indeed: generalist arthropod predators function as pest specialists at the late growth stage of rice

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**Associate Editor's Comments to the Author(s):**  
  
**Comment 1** > Thanks for your submission of the manuscript AGEE36058 titled ‘A predator in need is a predator indeed: generalist arthropod predators function as pest specialists at the late growth stage of rice’. This manuscript has been reviewed by two independent experts and their comments are copied below. As you will see, reviewers find the topic interesting however they find too much to criticize in relation to your manuscript which compromises its suitability for publication in AGEE. In particular, objectives and hypotheses are unclear. You should insist on the novelty of your study. The unbalanced design is questionable. More importantly, the method you used appears inappropriate: pest consumers were pooled at a taxonomic level rather too coarse (order) adequate isotopic signature resolution. The absence of intraguild predation is also highly intriguing and questions the significance of the results (especially how efficient spiders are in pest suppression). About the format, I agree with Reviewer#1 that Introduction and Discussion are excessively long. For all these reasons, I've resolved to decline the work with the option to resubmit. Should you ultimately choose to resubmit to AGEE, the expectation is that the commentary would be carefully and thoroughly accounted for in the revised manuscript.

**Response** > Thanks for inviting us to resubmit a revision of our manuscript. The constructive comments and suggestions from the two reviewers have greatly improved the contents and structure of the article. In particular, we have seriously addressed the major concerns pointed out above and made changes accordingly. Below we briefly summarize our responses to these comments; detailed information is provided in the point-by-point response in the following section.

First, regarding the unclear aims/objectives of this study, we have revised the last paragraph of the introduction section by removing the redundant objectives and adding some general expectations for our research aims. Please see our response to comment 9 by reviewer 2 for more details.

Second, to address the issue of unbalanced design (different numbers of farms across years), we have updated our GLM beta regressions by using weights based on the number of observations in each study year. This accounts for the unbalanced sampling by putting more emphasis on the patterns in years with more replicate farms and isotope samples. Please see our response to comment 19 by reviewer 2 for more details.

Third, we pooled our prey samples at the order level because the best practice in using stable isotope mixing models is to have the number of prey sources not exceeding the number of biotracers plus one (in our case three prey sources would be appropriate). Pooling samples at the family level would yield substantially more prey sources, introducing more uncertainties to the diet estimates. Moreover, the assignment of trophic guilds and subsequent pooling of prey samples in our study were based on a combination of dietary information in the literature and k-means clustering of carbon and nitrogen isotope signatures of arthropod samples. This procedure ensured separation among the prey sources in the iso-space for mixing model estimation. We have provided a stable isotope biplot of rice plant and prey sources in the appendix to demonstrate this (Appendix A: Fig. S1). Please see our response to comment 16 by reviewer 2 for more details.

Forth, this study did not quantify the degree of intraguild predation (IGP) in the farms as currently it is not possible to quantify IGP using stable isotope mixing models. We acknowledge that this is a limitation to our study and we did discuss it in the potential caveats. IGP could potentially reduce the effectiveness of predators in pest suppression. However, as pointed out in the potential caveats, we feel that IGP may not be a major concern in our study system because rice plants grow in dense clumps and form a complex structure that could reduce IGP. As suggested by reviewer 1, we have now brought up this limitation earlier in the discussion section. Please see our response to comment 1 by reviewer 1 for more details.

Finally, regarding the length of the introduction and discussion section, we have condensed the information and removed unnecessary contents to improve the clarity and readability of the manuscript.

GC’s thought: We probably need to trim the contents in the introduction and discussion section.

**Reviewer's Responses to Questions**

1. Are the objectives and the rationale of the study clearly stated? Please provide suggestions to the author(s) on how to improve the clarity of the objectives and rationale of the study. Please number each suggestion so that author(s) can more easily respond.

Reviewer #1: Yes

Reviewer #2:

1. Yes, the objectives stated but are entangles with the overall study goal; these need to be disentangled.

**Response** > We have revised the last paragraph of the introduction section by removing redundant objectives. Please see our response to comment 9 by reviewer 2 for more details.

1. The objectives imply work on generalist arthropods whereas only 2 groups of these (spiders and ladybeetles) were examined; most of the other generalist predators in rice-field systems (ants, ground beetles, earwigs, crickets, predatory bugs) were not part of the study.

**Response** > In our study farms, spiders and ladybeetles were the two most abundant predator groups, whereas other predators were rare or even absent in our samples (e.g., we did not have earwigs and ground beetles). We have explained this in our response to comment 6 by reviewer 2.

1. No hypothesis is stated, and while this might not be absolutely necessary, it would be useful to add a small bit about what the study's expectations generally were, for the conclusions to be viewed by the general readership from the perspective of whether or not such expectations were met/achieved.

**Response** > We have revised the last paragraph of the introduction section by adding some general expectations for our research aims. Please see our response to comment 7 by reviewer 2 for more details.

2. If applicable, is the application/theory/method/study reported in sufficient detail to allow for its replicability and/or reproducibility? Please provide suggestions to the author(s) on how to improve the replicability/reproducibility of their study. Please number each suggestion so that the author(s) can more easily respond.

Reviewer #1: Mark as appropriate with an X:  
Yes [X] No [] N/A []

Reviewer #2: Mark as appropriate with an X:  
Yes [] No [X] N/A []

Provide further comments here:

1. The sample sizes (number of farms) were unbalanced (3, 7 and 7 in the 1st, 2nd and 3rd years, respectively). There is need to clarify how the impact of this was addressed so as not to invalidate analyses methods applied.

**Response** > We have now updated our analyses to account for the unbalanced sample size by using weighted regressions based on the numbers of the observations in each year. Please also see our response to comment 19 by reviewer 2 for more details.

1. The sweep-netting strategy needs clarification (whether only ridge-side plants were swept, as the authors state, or a more representative method covering adequate sections of rice-field-plots were sampled). They speak of sweeping while walking along ridges.

**Response** > We have provided more details on our field sampling in our response to comment 11 by reviewer 2.

1. Need to add if field choice was randomized, and if so, how this was achieved for sampling independence.

**Response** > We have provided more details on our field site selection in our response to comment 13 by reviewer 2.

1. Sampling frequency not stated.

**Response** > We have provided more details on our field sampling in our response to comment 11 by reviewer 2.

1. 1-km buffer around farms to characterize forest cover effects on predation, is rather too far to have any impact on arthropod assemblages on the farms. the role of forest cover could well have been eliminated from the study.

**Response** > We have provided explanations for this in our response to comment 15 by reviewer 2.

3. If applicable, are statistical analyses, controls, sampling mechanism, and statistical reporting (e.g., P-values, CIs, effect sizes) appropriate and well described? Please clearly indicate if the manuscript requires additional peer review by a statistician. Kindly provide suggestions to the author(s) on how to improve the statistical analyses, controls, sampling mechanism, or statistical reporting. Please number each suggestion so that the author(s) can more easily respond.

Reviewer #1: Mark as appropriate with an X:  
Yes [X] No [] N/A []

Reviewer #2: Mark as appropriate with an X:  
Yes [] No [X] N/A []

Provide further comments here:  
1. Pest consumers were pooled at a taxonomic level rather too coarse (order) adequate isotopic signature resolution. Family level would have been much more acceptable.

**Response** > We have provided explanations for this in our response to comment 16 by reviewer 2.

1. Mention is made of beta regression (GLM or GLMM) but not mention of probability distribution of link function employed in such modelling.

**Response** > We have added more details on the model fitting procedure. Please see our response to comment 17 by reviewer 2 for more details.

1. Results of isotopic analyses of food proportions in predators diets using MixSIAR should be presented in form of median with credible intervals rather than means and standard errors.

**Response** > We have updated our analyses using posterior median estimates in place of posterior mean estimates from the MixSIAR model outputs. Please see our response to comment 21 by reviewer 2 for more details.

4. Could the manuscript benefit from additional tables or figures, or from improving or removing (some of the) existing ones? Please provide specific suggestions for improvements, removals, or additions of figures or tables. Please number each suggestion so that author(s) can more easily respond.

Reviewer #1: No

Reviewer #2:

1. There should be at least one table summarizing median and credible intervals of pest proportions in predator diets.

**Response** > We have clarified this in our response to comment 21 and 22 by reviewer 2.

1. Figures from the MixSIAR results should be presented in form of posterior density plots of medians, not linear graphs of means.

**Response** > We have clarified this in our response to comment 21 and 22 by reviewer 2.

1. Therefore tables and figures presenting results in form of means and standard errors should be removed.

**Response** > We have clarified this in our response to comment 21 and 22 by reviewer 2.

5. If applicable, are the interpretation of results and study conclusions supported by the data? Please provide suggestions (if needed) to the author(s) on how to improve, tone down, or expand the study interpretations/conclusions. Please number each suggestion so that the author(s) can more easily respond.

Reviewer #1: Mark as appropriate with an X:  
Yes [] No [X] N/A []

Reviewer #2: Mark as appropriate with an X:  
Yes [X] No [] N/A []

Provide further comments here:  
1. The results as currently presented are based on means and standard errors of MixSIAR models. These carry a high level of inaccuracy because MixSIAR model estimates of food source proportions are typically skewed, making means very vulnerable to effects of statistical tails. Medians are the most resilient to such impacts, but include credible intervals.

**Response** > We have now updated our analyses using posterior median estimates in place of posterior mean estimates to account for the skewed distributions. Please see our response to comment 21 and 22 by reviewer 2 for more details.

1. The authors state that generalist predators qualify as specialists because they have high proportions of pest food in their diets towards crop maturity, without providing justifiable evidence.

**Response** > We have clarified this in our response to comment 24 by reviewer 2.

1. Throughout the article, there is need to emphasize that the study was based on two groups of generalist predators only - (spiders and ladybeetles), and not make an overarching generalization for all generalist predators.

**Response** >

In our study system, spiders and ladybeetles were the two most dominant groups of generalist predators, and we feel that focusing on them should capture the majority of arthropod predator-prey dynamics in rice agroecosystems. Nonetheless, to be more accurate, we have replaced our original term “all predators” with “both predators”. Please also see our response to comment 2 and 6 by reviewer 2 for more details.

6. Have the authors clearly emphasized the strengths of their study/theory/methods/argument? Please provide suggestions to the author(s) on how to better emphasize the strengths of their study. Please number each suggestion so that the author(s) can more easily respond.

Reviewer #1: Yes

Reviewer #2: In general yes

**Response** > Thanks for the positive comments.

7. Have the authors clearly stated the limitations of their study/theory/methods/argument? Please list the limitations that the author(s) need to add or emphasize. Please number each limitation so that author(s) can more easily respond.

Reviewer #1: No

Reviewer #2: In the limitations/caveats subsection, the authors state that they are reluctant to imply actual pest suppression because they did not complement isotopic analyses (SIA) with direct field observation. The SIA technique is meant to more or less eliminate the need for direct field observation, or at least render it subliminal. Here it’s better to say that the study did not incorporate assessment of crop damage rates or yield gap data to support implications of pest suppression.

**Response** > Thanks for the suggestions. We have now added assessment of crop yield in the subsection “*4.4. Potential caveats of this study*”:

“Additionally, this study did not include an assessment of crop damage and rice production, and incorporating crop yield data would be necessary to evaluate the overall pest control effectiveness by predators.”

8. Does the manuscript structure, flow or writing need improving (e.g., the addition of subheadings, shortening of text, reorganization of sections, or moving details from one section to another)? Please provide suggestions to the author(s) on how to improve the manuscript structure and flow. Please number each suggestion so that author(s) can more easily respond.

Reviewer #1: Yes

Reviewer #2: Generally no, except for the need to clearly dis-engage or distinguish the study's mail aim/goal from objectives and hypothesis, putting all these in a stand-alone paragraph under Introduction section

**Response** > We have now revised the last paragraph of the introduction section by removing the redundant objectives and added some general expectations for our research aims. Please see our response to comment 9 by reviewer 2 for more details.

9. Could the manuscript benefit from language editing?

Reviewer #1: No

Reviewer #2: No

**Reviewer 1's Comments to the Author(s):**

**Comment 1** > In this paper the authors investigated the role of generalist and specialist predators in the rice ecosystem. They employed stable isotope approach to test three hypotheses. They found predation on pests increased over season, was similar across years, and was higher in conventional than organic farming. They conclude that generalist predators have potential to produce stable top-down effect. The study investigates an important topic, the design was adequate and the results are sound but not in current version.

I have two major concerns. At first, the role of generalist spider predators has been known for a long time. So in this respect the study does not bring anything novel. But the quantification of rice pest suppression is new. Yet, this is the main problem of the study. The isotopic analysis is not the best to be used to quantify trophic interactions as it lacks the precision. In particular, the absence of intraguild predation is intriguing. The estimates of predation on pests are thus biased to an unknown degree. This is a serious limit of the study. Unfortunately, the authors acknowledge this limit only in the very last part of Discussion, so the reader is impressed by reading the paper how efficient spiders are in pest suppression. The authors should either provide evidence that intraguild prey was scarce and therefore unlikely to form a significant proportion of the diet or state this limit in the beginning of the study.

In addition I find both Introduction and Discussion excessively long. For example, the first paragraph of Introduction could be omitted as it is too general.

**Response** > Thanks for the comments on our manuscript. Below we address the two concerns raised by reviewer 1:

1. Although stable isotope analysis may not be as precise as molecular methods, it does reveal time-integrated dietary patterns of consumers, which is suitable for the purpose of our study. In fact, stable isotope analysis has long been applied in trophic ecology and relevant methodologies have been developed over the past two decades (Quinby et al. 2020). Various studies have made good use of it to quantify predator-prey trophic interactions (e.g., Blumenthal et al. 2012, Manlick et al. 2019, Carbonell Ellgutter et al. 2020), and we feel that our stable isotope approach can provide useful information that helps improve our understandings of this field.
2. We acknowledge that intraguild predation (IGP) is a limitation to our study, and currently it is not possible to quantify IGP using stable isotope mixing models. However, as pointed out in the potential caveats, we argue that IGP may not be a major concern in our study system because rice plants grow in dense clumps and form a complex structure that could reduce IGP.

GC’s thought: I think we can briefly mention IGP earlier in the discussion section and refer readers to the potential caveats for more details (I’ve added a sentence of IGP to the last part of the first paragraph in the subsection “*4.1. Generalist predators function as rice pest specialists at late crop stages*”. Feel free to edit it further as you wish!). Regarding the length of the introduction and discussion section, I think we can still keep the original information there but reduce the contents to improve the overall readability.

References:

Quinby, B. M., Creighton, J. C., & Flaherty, E. A. (2020). Stable isotope ecology in insects: a review. Ecological Entomology, 45(6), 1231-1246.

Blumenthal, S. A., Chritz, K. L., Rothman, J. M., & Cerling, T. E. (2012). Detecting intraannual dietary variability in wild mountain gorillas by stable isotope analysis of feces. Proceedings of the National Academy of Sciences, 109(52), 21277-21282.

Manlick, P. J., Petersen, S. M., Moriarty, K. M., & Pauli, J. N. (2019). Stable isotopes reveal limited Eltonian niche conservatism across carnivore populations. Functional Ecology, 33(2), 335-345.

Carbonell Ellgutter, J. A., Ehrich, D., Killengreen, S. T., Ims, R. A., & Unnsteinsdóttir, E. R. (2020). Dietary variation in Icelandic arctic fox (Vulpes lagopus) over a period of 30 years assessed through stable isotopes. Oecologia, 192, 403-414.

**Specific comments**

**Comment 2** > Line 18: Rather than biocontrol use Conservation control.

**Response** > GC’s thought: Perhaps we can use “Conservation biocontrol” instead.

**Comment 3** > Lines 86-90: To test the hypothesis of consistency is trivial unless there is a reason why generalists as opportunists would switch to a different prey some years.

**Response** > The opportunistic feeding nature of generalists means that they could potentially shift their diets depending on the biotic and abiotic factors (e.g., climatic conditions), which can vary across years. Therefore, it would be important to examine the consistency in pest consumption by GAPs to better assess whether these predators can serve as effective and stable biocontrol agents.

**Comment 4** > Lines 125-128: Repetition of the former text. Omit it.

**Response** > We have removed this part in this revision.

**Comment 5** > Line 145: I am surprised to read that the conventional farms used only one application of insecticide per season. Is it really true?

**Response** > GC’s thought: I am not sure about this. We probably need to double-check the documents.

**Comment 6** > Lines 143, 145: Add information when the insecticides were applied.

**Response** > GC’s thought: I am not sure about this. We probably need to double-check the documents.

**Comment 7** > Line 147: How often sweeping was done? Once per growing stage?

**Response** > Yes, the sweeping was conducted once per crop stage.

**Comment 8** > Line 150: To what taxonomic level identification was performed? And how was it identified?

**Response** > The level of identification depends on the taxa. Most of the rice herbivore species were identified to genus level, whereas tourist herbivores and detritivores were mainly identified to family level (please see Appendix Table S1 for a list of major arthropod families/genera in each study year). The majority of arthropod samples was identified using insect pest handbooks in Taiwan and Southeast Asia; some samples (mostly diptera species) were sent to a taxonomy lab at the Entomology Department at National Taiwan University for expert identification.

**Comment 9** > Line 159: I wonder why there were only 352 predators but 828 prey samples if the study plots were dominated by a single pest species?

**Response** > The arthropod communities during the early crop season were generally more diverse and tended to be dominated by one or a few pest herbivores at late crop stages. Among the 828 prey isotope capsule samples, 66.4% (550 out of 828) were rice herbivores, of which 73.6% (405 out of 550) were planthoppers (Delphacidae/*Nilaparvata*) and leafhoppers (Cicadellidae/*Nephotettix*)(Note that a single species can have multiple isotope capsule samples, each of which may contain multiple individuals in order to meet the minimum weight requirement for stable isotope analysis.)

**Comment 10** > Lines 167-170: Omit definition of guilds.

**Response** > We have now removed this part.

**Comment 11** > Line 189: If samples at seedling stage were later omitted why do you earlier say that you collected data at four growing stages?

**Response** > We did collect arthropod samples at four crop stages during the first rice season in each study year. Even though the isotope capsule samples at the seedling stage were omitted from our stable isotope mixing model analysis, we still included the data on arthropod abundances in Fig. 3. That said, we have removed all mention of “seedling” stage when referring to stable isotope analysis of predators’ diet.

**Comment 12** > Line 203: How did you estimate the proportion of herbivores? This must have been done by the model. Explain.

**Response** > The data analyses in this study consisted of two parts. First, we ran Bayesian stable isotope mixing models to estimate the proportions of three prey sources (rice herbivores, tourist herbivores, detritivores) consumed in predators’ diet. Next, we extracted the posterior median estimates of rice herbivore consumption and fit beta regression models to examine the relationship between pest consumption by predators and various biotic and abiotic factors.

**Comment 13** > Lines 264-267: This belongs to Discussion.

**Response** > We have now moved the information to the discussion section.

**Comment 14** > Lines 269-270: I am surprised to read the absence of association between proportion of herbivores in the predator body and their abundance in the field. If spiders are generalists then there should be such association. This makes the obtained results suspicious.

**Response** > We did provide an explanation for why there was a lack of such association in the last paragraph of section 4.3. “*Factors associated with pest consumption by predators*”. Briefly, there did exist a simple bivariate correlation between the relative abundance of rice herbivores and the proportion of pest consumed by predators. However, the relative abundance of rice herbivores also increased over crop stages. When both factors were included in our beta regression models, most of the variations may have been explained by crop stage (which was indeed significant), leading to a non-significant result for the relative abundance of rice herbivores.

**Comment 15** > Lines 274-294: This is just repetition of results. Omit it.

**Response** > We feel that a summary of key results of our study is still necessary and can help orient the readers to the following sections.

**Comment 16** > Lines 331-344: This is trivial. Omit it.

**Response** > The consistency in pest consumption by predators over years is actually one of the most important findings in our study and we feel that it is worth talking about it in a separate section.

**Comment 17** > Lines 357-367: This is trivial. Omit it.

**Response** > Since we tested the effects of crop stage in our study, it would be logical to discuss it. Although the finding of increasing pest consumption toward later crop states may be expected, we disagree that it is trival as it provides useful implications for agricultural management.

**Reviewer 2's Comments to the Author(s):**

**Comment 1** > The study examined rates of consumption of a range of arthropod herbivores (pests) in rice-fields of Taiwan by spiders and lady beetles, by using stable isotopes mixing models MixSIAR) to estimate proportional contributions of these pests to predators' diels. They additionally evaluated the influence of some habitat variables in contributing to such pest consumption trends, comparing organic versus conventional farming systems over three consecutive years.

This is a very significant study, with potential to contribute immensely to the still narrow range of literature on the general subject of new techniques and strategies for quantifying pest biocontrol in cereal crops. It is also very timely, given the increasing value attachment to to non-chemical measures for mitigating crop damage by arthropod pests. The element of crop growth stage as a factor in determining pest consumption levels is especially interesting as it is rarely examined yet arthropod assemblage patterns, and presumably their trophic interactions do change with time.

While the study is generally well designed, it has a number of methodological gaps that would need to be addressed so as to put the results into proper perspective for conclusions to be justifiably drawn. These include wide generalizations about the range of predators examined (while only two taxonomic groups were involved), and combining pest consumers at taxonomic levels too course for isotopic analyses. Habitat variables' roles and how they were characterised are also not adequately described while samples (farm numbers) were not consistently balanced to justify temporal-scale comparisons. In addition, results of MixSIAR modelling that form the basis of the discussion and conclusions drawn are presented in form of means and standard errors while the conventional practice is to present medians and credible intervals. There are some inconsistencies (or gaps) in some non-MixSIAR analyses of data, particularly with regression, and a few non-clarifications on the study's objectives.

**Response** > Thanks for the comments and suggestions. Below we briefly address the main concerns raised by reviewer 2. Detailed information was provided in our point-by-point responses.

1. Wide generalizations about the range of predators examined: In our study farms, spiders and ladybeetles were the two most abundant predator groups, whereas other predators were rare or even absent in our samples (e.g., we did not have earwigs and ground beetles). Therefore, even though this study only examined spiders and ladybeetles, we feel that our results should still be fairly representative of the arthropod communities in rice agroecosystems in Taiwan. Nonetheless, to be more accurate, we have replaced our original term “all predators” with “both predators”. Please see our response to comment 2 and 6 for more details.
2. Combining pest consumers at taxonomic levels too course for isotopic analyses: The assignment of trophic guilds and subsequent pooling of prey samples in our study were based on a combination of dietary information in the literature and k-means clustering of carbon and nitrogen isotope signatures of arthropod samples. This ensured that the isotopic separation among the prey sources were maximized for isotope mixing model estimation. Therefore, even though the isotope samples were pooled at the order level, we feel that the three prey sources used in our analysis would be appropriate. Please see our response to comment 16 for more details.
3. Habitat variables' roles and how they were characterised are not adequately described: The “habitat variable” refers to variable at the landscape scale, which is the “percent forest cover” in our study. We have clarified this in the point-by-point response. Please see our response to comment 15 for more details.
4. Samples (farm numbers) were not consistently balanced: We have updated our analyses to account for the unbalanced sample size by using weighted regressions based on the numbers of the observations in each year. Please see our response to comment 19 for more details.
5. Medians and credible intervals should be presented: We agree that posterior medians would be more appropriate than posterior means as the posterior distributions are generally skewed, and all analyses have been updated using posterior medians in place of posterior means. The dietary patterns and main conclusions remain the same after the new analyses. Please see our response to comment 21 for more details.
6. Inconsistencies in regression: We have clarified some confusions about the GLM beta regressions and provided more details on our model fitting procedure. Please see our response to comment 17, 18, and 20 for more details.
7. Non-clarifications on the study's objectives: We have revised the last paragraph of the introduction section by removing the redundant objectives and adding some general expectations for the research aims. Please see our response to comment 9 for more details.

**Specific comments**

*Title*

**Comment 2** > The current title implies that all generalist predators were studied, which is not the case - only spiders and lady beetles were considered. Suggested change: Spiders and lady-beetles consume higher proportions of rice pests at late growth stages regardless of farming system. This is because there were only 2 predator groups examined here: spiders and lady beetles.

**Response** > Spiders and ladybeetles were the two most abundant arthropod predator groups and thus representative of the generalist predator community in our study system. As a result, we feel that it would be reasonable to keep “generalist arthropod predators” in the title. In fact, some studies examining certain groups of arthropod predators also used “generalist predators” in their article titles (e.g., Roubinet et al. 2017 and Staudacher et al. 2018; both focused mainly on spiders and ground beetles).

References:

Roubinet, E., Birkhofer, K., Malsher, G., Staudacher, K., Ekbom, B., Traugott, M., & Jonsson, M. (2017). Diet of generalist predators reflects effects of cropping period and farming system on extra‐and intraguild prey. Ecological Applications, 27(4), 1167-1177.

Staudacher, K., Rennstam Rubbmark, O., Birkhofer, K., Malsher, G., Sint, D., Jonsson, M., & Traugott, M. (2018). Habitat heterogeneity induces rapid changes in the feeding behaviour of generalist arthropod predators. Functional Ecology, 32(3), 809-819.

*Abstract*

**Comment 3** > 1. This is generally well summarised, but elements of it and some wordings/sentences will change after some of the results-presentation suggestions are addressed.

**Response** > We have updated the abstract based on the new analyses and results.

**Comment 4** > 2. Also the claim of predators being specialist towards crop maturity is unsupported by the results.

**Response** > We have clarified this in the response to comment 24.

*Introduction*

**Comment 5** > 1. The objectives stated but are entangled with the overall study goal; these need to be disentangled.

**Response** > We have now revised the last paragraph of the introduction section. Please see our response to comment 9 for more details.

**Comment 6** > 2. The objectives imply work on generalist arthropods whereas only 2 groups of these (spiders and ladybeetles) were examined; most of the other generalist predators in rice-field systems (ants, ground beetles, earwigs, crickets, predatory bugs) were not part of the study.

**Response** > In our study farms, spiders and ladybeetles were the two most abundant predator groups, whereas other predators were rare or even absent in our samples (e.g., we did not have earwigs and ground beetles). Therefore, even though this study only examined spiders and ladybeetles, we feel that our results should still be fairly representative of the arthropod communities in rice agroecosystems in Taiwan. Nonetheless, to be more accurate, we have replaced our original term “all predators” with “both predators”.

**Comment 7** > 3. No hypothesis is stated, and while this might not be absolutely necessary, it would be useful to add a small bit about what the study's expectations generally were, for the conclusions to be viewed by the general readership from the perspective of whether or not such expectations were met/achieved.

**Response** > We have added our general expectations for the research aims in the last paragraph of the introduction section:

“We expected that the patterns of pest consumption by GAPs may differ between organic and conventional farms, vary throughout the crop season as the relative abundances of different prey sources changed, be affected by the surrounding landscape composition (percent forest cover), and vary across years as the climatic conditions fluctuated.”

**Comment 8** > 4. The role of 'years', in my opinion would not make a significant value since the rice agronomic practices do not change much from year to year in the study area (Taiwan). Therefore the crop stages are enough as a time-based parameter.

**Response** > The opportunistic feeding nature of generalists means that they could potentially shift their diets depending on the biotic and abiotic factors (e.g., climatic conditions), which can vary across years despite the same rice agronomic practices. Therefore, in addition to the variations in diet compositions of GAPs over crop stages, it would be important to examine the consistency in pest consumption across years to better assess whether these predators can serve as effective and stable biocontrol agents.

**Comment 9** > 5. There is need to clearly distinguish among overall goal/aim(s), specific objectives, and the study's expectations or working hypotheses. As at now, they seem to be all mixed up towards the end of the introduction section.

**Response** > Thanks for the suggestions. We have now revised the last paragraph of the introduction section by removing the redundant objectives and adding some general expectations for the research aims:

“To address these three knowledge gaps, this study aimed to 1) quantify the diet composition of generalist arthropod predators (GAPs), 2) examine the consistency of GAPs in pest consumption over years, and 3) investigate how various abiotic and biotic factors may affect the diet composition of GAPs. Filling these gaps will provide useful insights for applying generalist predators in pest programs. Specifically, this study sampled arthropod prey and two main groups of GAPs (ladybeetles and spiders) in sub-tropical organic and conventional rice farms over the rice growth season (tillering, flowering, and ripening stages) in central Taiwan from 2017 to 2019, and quantified the diet composition of GAPs at each rice stage using carbon and nitrogen stable isotopes. We expected that the patterns of pest consumption by GAPs may differ between organic and conventional farms, vary throughout the crop season as the relative abundances of different prey sources changed, be affected by the surrounding landscape composition (percent forest cover), and vary across years as the climatic conditions fluctuated. Stable isotope analysis has been widely applied in ecology to infer predator-prey trophic interactions and to estimate the proportional contribution of different prey sources to predators’ diets in various ecosystems, especially in agricultural settings (Post, 2002; Boecklen et al., 2011; Layman et al., 2012). This quantification method reflects accumulated prey consumption in predators’ diets, which may not be revealed by other “snap-shot” techniques (e.g., field observations and molecular gut content analysis) (Newton, 2016).”

*Methods*

**Comment 10** > 1. Three farms in year one and 7 farms each in year 2 and 3 amounts to unbalanced sample size.

**Response** > Please see our response to comment 19 for more details.

**Comment 11** > 2. The authors need to more fully and clearly describe how mist-netting as conducted: it's not enough to say this was conducted while walking along ridges, because this implies sampling only insects along the field edges, rendering the collected samples unrepresentative.

**Response** > We have added some details on the sweep-netting in the methods section:

“At each major rice crop stages (seedling, tillering, flowering, and ripening stage) during the growing season (April - July) in each study year, we collected arthropod samples by walking along two randomly selected farm ridges and sweep-netting (36 cm in diameter with a mesh size of 0.2 × 0.2 mm) the crop canopy 30 times for each ridge. This allowed us to sample arthropod species inhabiting rice farms (e.g., rice herbivores) as well as those dispersing into the farms from nearby vegetation (e.g., tourist herbivores; see *2.3. Arthropod trophic guild assignment* for more details).”

**Comment 12** > 3. Sweeping for canopy insects also implies that insects on other aerial parts of rice were ignored: not all pests are to be found on rice canopies (under-representation or under-sampling).

**Response** > We agree that each sampling method comes with limitations and our sweep-netting might not capture the entire arthropod communities in rice farms. However, we were still able to sample the most important/dominant arthropod prey (brown planthopper, green leafhopper, various stink bug species) and predators (long-jawed orb weaver and ladybeetle). Therefore, we feel that our samples should be fairly representative of the arthropod communities in our study system.

**Comment 13** > 4. Also how plots were selected for sampling including distance separation between sampled plots, and how this was independent of arthropod movement patterns (to eliminate pseud-replication) will be desirable.

**Response** > We have now added some details on the farm selection in the methods section:

“We collected terrestrial arthropods in paired organic and conventional rice farms in subtropical Taiwan (120.656-120.721 °E; 24.364-24.489 °N) from 2017 to 2019 (three farm pairs in 2017 and seven farm pairs in 2018 and 2019). The sample sites where each farm pair was located were at least 1 km apart from each other to minimize the potential movements of arthropods across farms. The study farms were 0.2 hectares on average and irrigated with surface water.”

**Comment 14** > 5. It would have been useful if the study assessed the role of some surrounding vegetation on field margins (e.g., on ridges and levees) as a food source alternative to rice, and how it compares to rice as a contributor to pest diets. This is because it could be that the reason predators consume more rice prey in late stages is that at this time, drier conditions and no water support little growth of alternative plants such as on ridges and leaves, making herbivores move from there and be more abundant in rice. Consequently, predator-prey interactions are enhanced on rice, in which case the key explanatory factor here is therefore the watering regime rather than the crop stage. In the absence of this data/results, the authors need to adequately describe the structure of this kind of vegetation, including its persistence across the grow-out period and water availability, for there to be a clear picture as to why it might not have affected predator or pest dispersal or consumption rate results presented.

**Response** > The vegetation along the farm margins was mainly composed of poaceae species and an Asteraceae species *bidens pilosa*. As the flooding mostly affected the rice plant within the farms, the growth of these surrounding plants was by and large independent of water regime and they persisted over the crop season. It is possible that rice herbivores might have consumed some surrounding plants, but our data show that rice herbivores exhibited carbon isotope signatures more similar to those of rice plant (C3 signals) than tourist herbivores did (which fed primarily on the surrounding vegetation with C4 signals), suggesting that the effects of surrounding vegetation on the feeding of rice herbivores might be relatively minor (see the figure below; the figure has been added to the Appendix). Nonetheless, we agree that it would have been more informative to quantify the diet composition of herbivores from rice plants and other alternative food sources.

Biplot.tiff

**Figure S1**. Stable isotope biplot of rice plant and the three prey sources in the study. The points represent the mean values of isotope samples in respective prey guilds pooled across all three study years; error bars represent 95% confidence intervals.

Flooding may affect the movements of arthropods within the farms and between the surrounding vegetation and the farms, but in general the flooding and drainage practices followed the crop development, and thus crop stage would be a good proxy for water regime.

**Comment 15** > 6. The role of habitat variables in driving predation rates has been treated very subliminally: not included in the objectives, not thoroughly described in Methods as to how the habitat structure (forest cover, other vegetation on field margins etc) were measured. Mention is made of forest cover, but no details as to how this was measured either, other that GoogleEarth was used for estimates. How close within the 1-km buffer were the forests to the rice-fields, for there to be an expectation that arthropods they might influence predation rates on farms? A 1-km buffer around farms is quite wide and though a few mobile arthropods may disperse from there into farms (certainly not spiders and lady-beetles!!!), it will definitely not affect pest-predator trophic interactions.

**Response** > The “habitat variable” refers to variable at the landscape scale, which is the “percent forest cover” in our study. The distance between forest patches and the study farms depended on the site, ranging from less than a hundred to a few hundred meters. As there is no single standard for selecting the spatial scale of landscape variable, we followed the methods adopted by previous studies. For example, Rusch et al. (2016) quantified landscape composition within an 1-km radius around the field and showed that landscape simplification could affect the level of natural pest control. Another study by Karp et al. (2018) even quantified landscape composition within a 2-km radius of each study site to examine its effect on natural enemy and pest abundances as well as predation rates. In fact, it is not uncommon for many insects to travel a few hundred meters, and therefore an 1-km buffer would not be unreasonable. On the other hand, if the radius was too short (e.g., less than a hundred meters), there would not be forest patch around most of the study farms. Thus, we feel that quantifying the surrounding forest cover within an 1-km buffer would be a reasonable approach.

References:

Rusch, A., Chaplin-Kramer, R., Gardiner, M. M., Hawro, V., Holland, J., Landis, D., ... & Bommarco, R. (2016). Agricultural landscape simplification reduces natural pest control: A quantitative synthesis. Agriculture, Ecosystems & Environment, 221, 198-204.

Karp, D. S., Chaplin-Kramer, R., Meehan, T. D., Martin, E. A., DeClerck, F., Grab, H., ... & Wickens, J. B. (2018). Crop pests and predators exhibit inconsistent responses to surrounding landscape composition. Proceedings of the National Academy of Sciences, 115(33), E7863-E7870.

*Analyses*

**Comment 16** > 1. Combining/pooling pest consumers at order level seems very course for isotopic signature resolution. In stable isotopic analyses, pooling up consumers' food sources into similar guilds is usually a generally acceptable and realistic strategy which helps in saving time, effort and costs without risk of losing signature resolution for food source signatures in predators, for instance. However, this should usually be done at as low a taxonomic level as possible, say genus or family. Pooling food sources at order level seems like a rather wide stretch, not least because at that level, despite guild-commonality, feeding systems are so variant as to erode isotopic signature resolution roles of component groups in contributing to consumer diets. In your case, grouping grasshoppers with beetles is rather strange, especially as you said earlier that former has no trophic link to rice. Putting hemiptera and lepidoptera is equally awkward since some hemiptera are generalist predators or omnivores. Finally, omitting crickets as part of detritivores is curious.

**Response** > The best practice in using stable isotope mixing models is to have the number of prey sources not exceeding the number of biotracers plus one. Since there were only two biotracers (carbon and nitrogen) in our study, three prey sources would be suitable for model estimation. Pooling samples at the family or genus level would yield substantially more prey sources, introducing more uncertainties to the diet estimates.

The assignment of trophic guilds and subsequent pooling of prey samples in our study were based on a combination of dietary information in the literature and k-means clustering of carbon and nitrogen isotope signatures of arthropod samples. This ensured that the isotopic difference among the prey sources and the isotopic similarity within the same source were maximized (the three prey sources were separated in the iso-space as shown in the figure below). Therefore, even though the isotope samples were pooled at the order level, we feel that the three prey sources used in our isotope mixing model analysis would be appropriate. We have provided some details on our trophic guild assignment in the methods section and added a stable isotope biplot of rice plant and prey sources to the Appendix (Appendix A: Fig. S1):

“The classification of prey guilds was based on a combination of dietary information in the literature and k-means clustering of stable isotope signatures of arthropod samples, which ensured that the isotopic separation among the three prey sources were maximized for stable isotope mixing model estimation (see Appendix A: Fig. S1 for a stable isotope biplot of rice plant and the three prey sources).”

Biplot.tiff

**Figure S1**. Stable isotope biplot of rice plant and the three prey sources in the study. The points represent the mean values of isotope samples in respective prey guilds pooled across all three study years; error bars represent 95% confidence intervals.

Regarding the grouping of arthropod taxa, grasshoppers and leaf beetles fed primarily on the vegetation around the farm ridges and thus were assigned to the same trophic guild. The main Hemiptera species in our study were sap feeders of rice plants (planthoppers, leafhoppers, and stink bugs), not generalist predators or omnivores. Finally, there were not many crickets in our field samples, plus their diets were relatively variable, and therefore they were excluded from the analyses.

**Comment 17** > 2. Mention is made of beta regression but not probability distribution or link function applied, or whether this was conducted using GLM or GLMM modelling.

**Response** > We have now added more details on our data analyses:

“To examine how local abiotic and biotic factors may affect the pest consumption by GAPs, we fit generalized linear models (GLM) with a beta distribution and a logit link function using the R betareg package (Zeileis et al., 2016), with year, farm type, crop stage, percent forest cover, and the relative abundance of rice herbivores as fixed effects and the proportion of rice herbivores consumed in predators’ diet as the response (posterior medians from the Bayesian stable isotope mixing models).”

**Comment 18** > 3. ANOVA procedure is stated to have been applied to analyse some data that were supposedly analysed using beta regression. Why would such repetition be necessary?

**Response** > The “Anova” function was applied to the GLM beta regressions to assess the significance of each factor in the model using the likelihood ratio test. It was not used to perform the analysis of variance (not to be confused with the function name).

**Comment 19** > 4. From the unbalanced sample size 3, 7 and 7 farms) across the three years, assessment of the role of years would have required a statement as to how such imbalance was addressed before analyses were performed in beta regression, e.g., incorporating a Kenward-Roger approximation with an autoregressive data structure, so as to reduce the impact of data heterokedascicity.

**Response** > We have now updated our analyses to account for the unbalanced sample size by using weighted regressions based on the numbers of the observations in each year.

**Comment 20** > 5. It is also not clear whether the interactive influences of the various explanatory factors were performed on mean, medial or other values of food-source proportions from MixSIAR, of from other datasets. This should be clarified.

**Response** > We have now added more details on our data analyses:

“To examine how local abiotic and biotic factors may affect the pest consumption by GAPs, we fit generalized linear models (GLM) with a beta distribution and a logit link function using the R betareg package (Zeileis et al., 2016), with year, farm type, crop stage, percent forest cover, and the relative abundance of rice herbivores as fixed effects and the proportion of rice herbivores consumed in predators’ diet as the response (posterior medians from the Bayesian stable isotope mixing models).”

*Results*

**Comment 21** > 1. The results of the isotopic mixing models for pest contributions to predator diels should be presented in form of Medians accompanied corresponding by credible intervals, instead of Means and standard errors as the authors have done. This is because normally, the mean is more relevant when aspiring for a definite hypothesis test with normally-distributed (or transformed data) to reduce skewing and so we can test to get a p=value 0.05 etc.) because mean is very sensitive or vulnerable to errors arising from long statistical-distribution tails. By contrast, with the Bayesian MixSIAR modelling, food proportion estimates, are almost always skewed so a measure of means is even more vulnerable to such impacts of tails (skewing), and the better option is therefore to use the median, which has the least sensitivity to skewed tails (compared to means or modes). But one has to provide the credible intervals to accompany the medians, just as you need SD (not just SE as the authors have done here) to accompany means in direct hypothesis tests. Therefore, the authors need to go back to their MixSIAR model results isotopic results and construct results based on medians. For details on this, see various articles by Brian Stock and Semmens.

**Response** > Thanks for the suggestions. We would like to clarify some confusions about our analyses here:

The original analyses consisted of two parts: (1) estimating predators’ diet composition using Bayesian stable isotope mixing models and (2) examining the effects of various factors on pest consumption by predators using GLM beta regressions. In the first part, we estimated the proportions of three prey sources consumed in predators’ diets at each crop stage in each individual farm in each study year. The Bayesian mixing models would return a posterior distribution for each of the three prey sources at each crop stage in each individual farm in each study year. This part of analyses is where the posterior means, medians, and credible intervals lied.

In the second part, we extracted the posterior mean estimates for rice herbivores from the posterior distributions for each crop stage × individual farm × study year combination returned by the mixing models, and fit weighted GLM beta regressions to examine the effects of various abiotic and biotic factors on rice pest consumption by predators. We also summarized the posterior mean estimates by farm type and crop stage in each year in the line charts (Fig. 1, Fig. 2, Fig. S2) and Table S2. This part of analyses is where the means and SEs lied (i.e., the means and SEs of posterior means).

We agree that the diet estimates by Bayesian stable isotope mixing models are often skewed and posterior medians would be a better measure of the Bayesian distributions than posterior means. In this regard, we have re-fit the GLM beta regressions using posterior medians in place of posterior means and updated the results, discussion, figures, and tables accordingly. Overall, the dietary patterns and conclusions were the same as previous ones.

**Comment 22** > 2. The results of the medians should consequently be presented in at least 1 table, and also the figures should preferably be presented in form of posterior median density plots (usually generated automatically by MixSIAR) rather than the linear graphs presented here by the authors.

**Response** > We have updated Fig. 1, Fig. 2, Fig. S2, and Table S2 by using means and SEs of posterior medians in place of posterior means.

As explained in the response to comment 21, we estimated diet composition of predators at each crop stage in each individual farm in each study year. This yielded a total of more than a hundred of posterior density plots. However, since we extracted the posterior medians for GLM beta regressions and figure/table displays, we feel that it might not be that helpful to show all of the individual density plots. That said, we provide an example below to showcase the posterior distributions for one of the study farm pairs in 2017:

density_plot

**Comment 23** > 3. After that results change, the patterns and trends in food source contributions to consumer diets will change a lot, the authors will the need to re-write results section.

**Response** > We have updated the results and discussion section based on the new analyses using posterior median estimates. The patterns and conclusions were generally the same as previous ones.

**Comment 24** > 4. There is not justifiable case for implying that because proportions of pests in generalist predators diets are relatively higher towards crop maturity, these predators then become specialists. You would have to quantify each of the component herbivores individually to see if they are consuming only one type at that stage (diet specialization/monophagy).

**Response** > Thanks for pointing this out. Yes, the diet of predators in our study consisted of various rice herbivore species at late crop stages and thus they were still “generalists” by definition. What we would like to highlight is that these predators functioned as specialists of rice herbivores as a whole trophic guild (i.e., guild-level specialist, not species-level specialist). To avoid the confusion, we have now clarified this in the discussion section:

“The results provide not only strong support for using GAPs in sustainable pest management, but also a novel aspect in biocontrol—generalist predators may function as guild-level specialist predators of rice pests during the late crop season.”

**Comment 25** > 5. The role of habitat variables in driving predation rates have not been clearly treated in results, so it is not easy to see how they influenced observed predation patterns. They could well be eliminated from the paper.

**Response** > The effect of percent forest cover on pest consumption by GAPs was indeed provided in the subsection “*3.3. Factors associated with rice herbivore consumption by predators*”.

*Discussion*

**Comment 26** > 6. I have largely hesitated to review this section due to the changes that will likely results from the presentation of results of Median instead of Mean proportional contributions of pests to predator diets because after that results change, the patterns and trends in food source contributions to consumer diets will change a lot, the authors will the need to re-write discussion and conclusion sections.

**Response** > We have updated the discussion and conclusions section based on the new analyses and results. Overall, the patterns and conclusions were the same as previous ones.